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Reporting Summary

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Statistical parameters

When statistical analyses are reported, confirm that the following items are present in the relevant location (e.g. figure legend, table legend, main text, or Methods section).

n/a	Confirmed	
☐	☒	The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☒	☐	An indication of whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒	The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☐	☒	A description of all covariates tested
☒	☐	A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒	A full description of the statistics including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☒	☐	For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☐	☒	Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated
☐	☒	Clearly defined error bars *State explicitly what error bars represent (e.g. SD, SE, CI)*

Our web collection on statistics for biologists may be useful.

Software and code

Policy information about availability of computer code

Data collection	Custom written Matlab/Simulink routines were written to collect the data in this paper.
Data analysis	Custom written Matlab and Python / numpy routines were written to analyze the data. Further, TensorFlow was used to write the main LFADS training algorithm, which is publicly available at https://github.com/tensorflow/models/tree/master/research/lfads Additional training and data routines, as well as a documentation and a matlab interface are available at https://github.com/lfads/lfads-run-manager/

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors/reviewers upon request. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Research guidelines for submitting code & software for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

> Data from non-human primates are available upon reasonable request.
> Data from human research participants cannot be made available due to patient privacy / HIPAA.

Field-specific reporting

Please select the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☒ Life sciences   ☐ Behavioural & social sciences   ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/authors/policies/ReportingSummary-flat.pdf

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

Sample size	For the maze analyses (Fig. 2) and perturbation analyses (Fig. 5), >2000 trials were used, which far exceeds the general standards for the field. For the LFADS/GPFA decoding comparison (Fig. 2e), enough random draws of neurons were selected to ensure there was no overlap between the populations being compared. For the stitching analysis (Fig. 5), the number of sessions used (44) is far greater than is typical for the field.
Data exclusions	All exclusions were performed without regard to the outcome of the study. For the stitching analysis, datasets were excluded if the datasets did not contain enough trials to fit a model (i.e., datasets with fewer than 200 trials were excluded). For all other analyses, trials were excluded if the animal failed to complete the task.
Replication	To ensure replication, we created a comprehensive, open-source framework so that other users can apply our analyses. We have also created open-sourced code that generates standardized datasets that can be used to replicate the methods. The latter is included as part of the LFADS training algorithm, (publicly available: https://github.com/tensorflow/models/tree/master/research/lfads). The former are included with documentation and the full Matlab interface (publically available: https://github.com/lfads/lfads-run-manager/)
Randomization	For the neuron-dropping analysis (Fig. 2e,f), neurons were randomly subsampled from the full neural population without replacement using a pseudo-random number generator. Number of random sets for each population size (25, 50, 200, 150) was chosen as sufficient to verify that the populations were non-overlapping.
Blinding	All data were originally collected for studies prior to the current study. Therefore experimental design for all data collection was not influenced by the goals of the current study.

Reporting for specific materials, systems and methods

Materials & experimental systems

n/a	Involved in the study
☒	Unique biological materials
☒	Antibodies
☒	Eukaryotic cell lines
☒	Palaeontology
☐	☒ Animals and other organisms
☐	☒ Human research participants

Methods

n/a	Involved in the study
☒	ChIP-seq
☒	Flow cytometry
☒	MRI-based neuroimaging

Animals and other organisms

Policy information about [studies involving animals](#); [ARRIVE guidelines](#) recommended for reporting animal research

Laboratory animals	Data from 2 rhesus macaques were used in this study: Monkey J (male, 7 & 14 years old at the time of data collection) and

Laboratory animals	monkey P (male, 8 years old at the time of data collection).
Wild animals	No wild animals were used in this study.
Field-collected samples	No field-collected samples were used in this study.

Human research participants

Policy information about studies involving human research participants

Population characteristics	Data used were from two research participants with paralysis. Permission for these studies was granted by the US FDA (IDE) and Institutional Review Boards of Stanford University, Partners Healthcare/Massachusetts General Hospital, the Providence VA Medical Center, and Brown University. Participants in this study were enrolled in a pilot clinical trial of the BrainGate Neural Interface System. Informed consent, including consent to publish, was obtained from the participants prior to enrollment. Pariticipant T7 was a male, 54 years old at the time of the research collections in the reported study. Participant T5 is a male, 63 years old at the time of the research sessions reported in this study. The conclusions of this study are independent of specific characteristics of the research participant population enrolled in this study.
Recruitment	Permission for these studies was granted by the US FDA (IDE) and Institutional Review Boards of Stanford University, Partners Healthcare/Massachusetts General Hospital, the Providence VA Medical Center, and Brown University. Participants in this study were enrolled in a pilot clinical trial of the BrainGate Neural Interface System. Informed consent, including consent to publish, was obtained from the participants prior to enrollment. Recruitment of participants matched the guidelines of the trial as set forth by the FDA IDE and IRBs. Participant recruitment has no effect on any conclusions of this study.

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☐ Initial submission   ☒ Revised version   ☐ Final submission

Editorial Policy Checklist

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Policy information about competing interests

Competing interests declaration
In the interest of transparency and to help readers form their own judgements of potential bias, Nature Research journals require authors to declare any competing financial and/or non-financial interest in relation to the work described in the submitted manuscript.

☒ No, I declare that the authors have no competing financial or non-financial interests as defined by Nature Research.

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Policy information about availability of data

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- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

☒ A full data availability statement is included in the manuscript.

Mandated accession codes (where applicable)
Confirm that all relevant data are deposited into a public repository and that accession codes are provided.

☐ All relevant accession codes are provided   ☐ Accession codes will be available before publication   ☒ No data with mandated deposition

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Unprocessed data must be provided upon request. Please double-check figure assembly to ensure that all panels are accurate (e.g. all labels are correct, no inadvertent duplications have occurred during preparation, etc.).

Data distribution
Present data in a format that shows data distribution (dot-plots or box-and-whisker plots).

Define all box-plot elements (e.g. center line, median; box limits, upper and lower quartiles; whiskers, 1.5x interquartile range; points, outliers).

If using bar graphs, overlay the corresponding dot plots.

☒ Confirm that all data presentation meets these requirements and that individual data points are shown.

Specific policy considerations

Some types of research require additional policy disclosures. Please indicate whether these apply to your study. If you are not certain, please read the appropriate section before selecting a response.

Does not apply	Involved in the study
☐	☒ Custom software or computer code
☒	☐ Macromolecular structural data
☐	☒ Research animals and/or animal-derived materials that require ethical approval
☐	☒ Human research participants
☒	☐ Clinical data

▶ Code availability

Policy information about availability of computer code

Code availability statement

For all studies using custom code, the Methods section must include a statement under the heading "Code availability" describing how readers can access the code, including any access restrictions.

☒ A full code availability statement is included in the manuscript

▶ Research animals

Policy information about studies involving animals; ARRIVE guidelines recommended for reporting animal research

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Policy information about studies involving human research participants

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Informed consent

☒ Confirm that informed consent was obtained from all participants.

Identifiable images

For publication of identifiable images of research participants, confirm that consent to publish was obtained and is noted in the Methods.

Authors must ensure that consent meets the conditions set out in the Nature Research participant release form.

☐ Yes   ☒ No identifiable images of human research participants

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Typed signature   David Sussillo, PhD _____   Date   04/20/2018 _____